MSFC-STD-509
October 16, 1972

GEORGE C. MARSHALL SPACE FLIGHT CENTER

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION

STANDARD

LUBRICANT SELECTION

GEORGE C. MARSHALL SPACE FLIGHT CENTER

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION

Standard

Lubricant Selection

MSFC-STD-509

1. This standard has been approved by the George C. Marshall Space Flight Center (MSFC) and is available for use by MSFC and Associated Contractors.

2. All recommended changes shall be submitted to the Chairman of the MSFC Specification Coordination Board, S&E-S/P-SC, Marshall Space Flight Center, Alabama 35812, for coordination with the cognizant design activity.

FOREWORD

The purpose of this standard is to provide criteria applicable to the selection of lubricants for use in Space Vehicles and Ground Support Equipment. Included also are requirements for the preparation of a lubrication plan for all machine elements that require lubrication.

1. SCOPE

1.1 Scope. - This standard presents requirements applicable to the selection of lubricants for use in space vehicles and ground support equipment. The requirements presented apply to all procuring activity or contractor design organizations responsible for selection of lubricants to be used on sliding or rolling components.

1.2 Classification. - Lubricants covered herein are classified as follows:

Class 1 - Solid

Class 2 - Fluid

2. APPLICABLE DOCUMENTS

2.1 The following documents form a part of this standard to the extent specified herein. Unless otherwise indicated, the issue in effect on date of invitation for bids or request for proposals shall apply.

SPECIFICATIONS

George C. Marshall Space Flight Center

MSFC-SPEC-106B	Testing Compatibility of Materials for Liquid Oxygen Systems

DRAWINGS

George C. Marshall Space Flight Center

50M02442	ATM Material Control for Contamination Due to Outgassing

PUBLICATIONS

National Aeronautics and Space Administration (NASA)

NHB 8060.1	Flammability, Odor and Offgassing Requirements and Test Procedures for Materials in Environments Which Support Combustion

George C. Marshall Space Flight Center

TM X-985	Compatibility of Materials With Liquid Oxygen
TM X-53052	Compatibility of Materials With Liquid Oxygen
TM X-53533	Compatibility of Materials With Liquid Oxygen, III
TM X-53773	Compatibility of Materials With Liquid Oxygen, IV

Midwest Research Institute Report

Control No. DCN-1-1-50-13616(1F) Lubrication Handbook for use in the Space Industry
Contract No. NAS8-27662

(Copies of specifications, standards, procedures, drawings, and publications required by suppliers in connection with specific procurement functions should be obtained from the procuring activity or as directed by the contracting officer.)

3. DEFINITIONS

3.1 Lubricant. - Any material which is interposed between two surfaces to reduce friction or to reduce wear.

3.2 Solid Lubricants. - Soft metal films, plastics, and other films or compacts containing lubricating powers. These materials provide lubrication to two relative moving surfaces under essentially dry conditions.

3.3 Fluid Lubricants. - Natural or synthetic oils and greases containing lubricating powers. These materials provide lubrication by the development of fluid films between two relative moving surfaces.

NOTE

Under certain conditions/applications, air or water may be considered a fluid lubricant.

4. GENERAL REQUIREMENTS

4.1 Selection Criteria and Available Information. - Maximum use shall be made of the criteria contained in Lubrication Handbook for Use in the Space Industry identified by Control Number DCN-1-1-50-13616(1F), Contract Number NAS8-27662. This criteria shall be considered in the selection of lubricants for specific applications and is not to be considered to cover all elements of machine application. In addition, Appendix A of this standard contains tabulations of fluid and solid lubricants and suggested uses for each with specific mechanisms. A listing of available fluid lubricants and their general characteristics and uses are contained in Table I. This lising is not to be considered all inclusive; other lubricants may be approved for specific applications. A partial listing of solid lubricants and their general characteristics is contained in Table II. Tables III and IV provide information on lubrication characteristics and uses that are helpful in the selection of lubricants for specific applications.

NOTE

In general, fluid lubricants provide better lubrication and longer wear life than do solid lubricants under normal operating environments and conditions. In some regimes of temperature, vacuum, and loading, solid lubricants have advantages. Careful selection of a solid lubricant may provide a solution to a particular problem.

4.2 Fluids. - Fluid lubricants are most effective where thick film lubrication (metallic surfaces are separated by a fluid film thicker than the total height of the metal asperities) can be used and shall generally be acceptable for such application. The most widely used fluid lubricants are mineral oils or greases formulated of mineral oils and soap thickeners. Mineral oils containing various additives such as detergents, extreme pressure (EP) materials, or viscosity levelers shall be acceptable where design or operating conditions permit or dictate the use of such additives. Synthetic oils formulated for use under extreme conditions of temperature, load, or environment shall also be used where conditions permit. Special EP additives shall be required where boundary layer lubrication (metal asperities contact) exists. Required film thickness shall be determined as a function of fluid viscosity and relative sliding speed of the surfaces, and an inverse function of load.

4.3 Solids. - Solid lubricants shall be used only under conditions of load, temperature, or vacuum where fluids are not recommended.

CAUTION
Solid films shall not be used as a substitute for fluid lubricants since the friction of solid lubricants is generally relatively high and the wear life of solids seldom matches that of a good fluid lubricant.

The most commonly used solid lubricants for space applications are polytetrafluoroethylene or molybdenum disulfide (MoS_2). See Paragraph 4.1. These materials are used in many forms and are often mixed with other materials. In general, solid lubricants shall not be used at high sliding speeds since they do not provide any method of removing heat from the contacting surfaces.

5. DETAILED REQUIREMENTS

5.1 Lubrication Plan. - The activity responsible for the design of machine elements that require lubrication shall develop a lubrication plan and obtain procuring activity approval prior to the date established for Preliminary Design Review (PDR). As a minimum the plan shall include:

a. The type machanism (gears, bearings, etc.) to be lubricated.
b. The anticipated loads (unit stress) and speed anticipated.
c. Ambient temperatures and atmosphere.
d. Total life requirements.
e. Documentation; specifications, standards, and computer data. (Computer data shall contain a reference to documents which describe the computer program or should explain the proposed program in detail. Also, an explanation of inputs and outputs shall be provided with calculations to be performed in order to provide output. An explanation of how computer programs will be used in the design process is also required.)
f. Methods of qualification and acceptance of selected lubricants.

5.2 Lubricant Compatibility. - Lubricants shall meet the compatibility requirements for the conditions of use (e.g. temperature, vacuum outgassing, LOX/GOX, flammability, etc.). Lubricants for LOX/GOX environments shall be selected from acceptable listing of TMX-985, TMX-53052, TMX-53773, TMX-53533 or shall be acceptable when tested in accordance with MSFC-SPEC-106. Materials to be utilized in space environments where outgassing and redeposition on optical surfaces is a problem shall be selected from acceptable lubricants listed in 50M02442. Where flammability is a

consideration, lubricants used shall meet the requirements of NHB 8060.1.

5.3 Documentation. - Lubricants selected for aerospace application shall be defined by specifications or standards in terms of composition or performance characteristics and supporting tests and inspections to verify that the lubricant meets these composition and performance characteristics. When required by the procuring activity the contractor or in-house design organization shall provide certification in writing attesting that the lubricants used meet the requirements to which the material was qualified.

Notice. - When Government drawings, specifications, or other data are used for any purpose other than in connection with a definitely related Government procurement operation, the United States Government thereby incurs no responsibility nor any obligation whatsoever; and the fact that the Government may have formulated, furnished, or in any way supplied the said drawings, specifications, or other data is not to be regarded by implication or otherwise as in any manner licensing the holder or any other person or corporation, or conveying any rights or permission to manufacture, use, or sell any patented invention that may in any way be related thereto.

Custodian:

NASA - George C. Marshall Space Flight Center

Preparing activity:

George C. Marshall Space Flight Center

APPENDIX A

The following tables represent general guidelines to be used in selection of fluid or solid lubricants with a reference to types of mechanisms with which used.

Table I. Fluid Lubricants

Characteristics							
Lubricant	Lubricity	(2) Viscosity Change With Temperature	(4) Temperature Range	Vacuum Compatibility	LOX/GOX (1) Compatibility	Corrosion (3) Protection	Cost
Mineral Oil	Good with Additives	High	Poor	Poor (5)	No	Good	Low
Diesters	Fair	High	Good	Fair	No	Good	Low
Silicones	Poor	Low	Excellent	Fair to Good	No	Poor to Fair	Moderate
Fluorosilicones	Fair	Low to Medium	Good	Good	No	Poor to Fair	Moderate
Chlorofluoro-carbon	Excellent	High	Good	Fair to Good	Yes	Poor	Moderate
Perfluorocarbon	Good	Medium to High	Good	Good	Yes	Poor	High

(1) All materials must meet the requirements of MSFC-SPEC - 106B and NHB 8060.1.
(2) Changes with particular formulation.
(3) Some materials may be improved with additives.
(4) The serviceable temperature range depends on viscosity-temperature relationships and also the limits that must be observed to avoid chemical or physical changes. (e.g., mineral oils undergo chemical changes that restrict high temperature service.)
(5) Except highly refined oils developed especially for vacuum.

Table II. Solid Lubricants

Characteristics						
Lubricant	Uses	Temp. Range °F (1)	Load Carrying Capability	Sliding Life	LOX/GOX (2) Compatibility	Coefficient of Friction (3)
Thin Metal Films, Gold, Silver	Rolling Element Bearings	-400 to 1300	Fair	Poor	Yes	0.1 to 0.3
Teflon & Reinforced Teflon	Ball Bearing Cages, Journal Bearings	-400 to 400	Poor to Fair	Good at Low Speeds	Yes Specific CPD must be eval.	0.03 to 0.4
Polymide	Ball Bearing Cages, Journal Bearings, Gears	-400 to 500	Fair	Good at Low Speeds	No	0.1 to 0.4
Unbonded MoS_2 Films	Rolling Element Bearing Race Lubes	-400 to 500 In Air	Fair	Poor	Yes	0.1 to 0.2
Sputtered MoS_2	Rolling Element Races and areas where thin films required	-400 to 500 In Air	Good	Fair	Yes	0.1 to 0.2
MoS_2 Films Applied by Gas Blast	Rolling Element Races and Light Load Sliding Surfaces	-400 to 500 In Air	Fair	Poor	Yes	0.1 to 0.2
MoS_2 Film Bonded with Inorganic Binder	Low Speed Ball Brg. Races, Journal Brgs., Sliding Surfaces, Fasteners	-400 to 700 In Air	Good to Excellent	Fair to Excellent	Yes	0.04 to 0.2
MoS_2 Bonded with High Temp. Organic Binder	Journal Brgs., Gears, Sliding Surfaces, Fasteners	-400 to 700	Good to Excellent	Good	No	0.08 to 0.2
CaF_2 and mixed fluorides, fused and inorganically bonded	Journal Brgs., Sliding Surfaces, Fasteners	500° to 1800°	Good	Fair to Good	Yes	0.1 to 0.4

(1) Usually higher in vacuum
(2) Material must meet the requirements of NHB 8060.1.
(3) Depends on load

Table III. Mechanism

Lubricant	Journal Bearings	Rolling Bearings	Gears	Sliding Surfaces
Mineral Oils	Use hydrodynamic lubrication at high speeds. Use in earth ambient conditions.	Use with all bearings operating in earth ambient environment. Usually use in grease form. Select viscosity on basis of load, speed, and temp.	Use E.P. greases in earth ambient condition. For long life, arrange for replacement of grease.	Use in earth ambient conditions. Arrange for lube replacement where possible.
Diesters	Use for high temp. conditions or limited life in vacuum.	Use for high temp. conditions or limited life in vacuum. Use for high humidity conditions.	High temp. operating condition. Load carrying capability fair.	High temp. operation load carrying capability fair.
Fluorosilicones	Use for wide temp. range and fair lubrication, Watch for dynamic corrosion.	Use for wide temp. range. Fair life in vacuum, Watch for dynamic corrosion.	Use for wide temp. range and moderate loads.	Use for wide temp. range and moderate loads.
Silicones	Limit use to very low loads. Watch for corrosive environments.	Use where high viscosity index is important. Good at high and low temperatures. Watch for dynamic corrosion.	Do not use if other materials are available.	Do not use if other materials are available.
Chlorofluorocarbons	Use for high temp. and extreme loads. Corrosion Major Problem.	Use for high temp. and high loads. Corrosion Major Problem Use for LOX service.	High temp. and LOX compatibility OK. Will carry high loads, but Does Not Provide Corrosion Protection.	Use for LOX service but not at low temp. Watch for Corrosion Will carry very high loads.
Perfluorinated Ethers	Chemically inert and good lubricant. Watch for corrosion. Low temp. limited.	Good vacuum lube, Good at high temp. Chemically inert. Watch for Corrosion. Low temp. limited	Excellent at high temp. or vacuum. Can be used in vicinity of LOX. Watch for dynamic corrosion.	Good in vacuum or at high temp. Good load carrying capability.

Table IV. Mechanism

	Journal Bearings	Rolling Bearings	Gears	Sliding Surfaces
Thin Metal Films	Use only at very high temp. Short wear life & low loads.	Use at very high temperature. Fair wear life.	Use at very high temp. for very short life. Better lubes probably available.	Use at low load. Better lubricants probably available.
Teflon & Reinforced Teflon	Use only at low speed and low load, vacuum.	Use as brg. cage for vacuum. Moderate wear life if temp. range is not too high.	Use reinforced Teflon for extremely light loads only. Do not use pure Teflon.	Use only for low speed, light loads.
Polyimide	Useful in vacuum. Fairly high coefficient of friction in air.	Tests made as cage material. Probably not as good as Teflon.	Useful as light to moderate load for gears in vacuum.	Use for low speed only.
Unbonded MoS_2 Films	Poor wear life.	Can be used as race lubricant in conjunction with sacrificial cage.	Very poor wear life.	Poor wear life.
Sputtered MoS_2	Can be used where necessary. Fair to poor wear life.	For special use applied to race. Fair life.	For small gears, wear life fair to poor.	Very thin film. Fair to poor wear life.
MoS_2 Film Bonded with Inorganic Binders	Generally, LOX compatible. Fair wear life at moderate to low speed. Good at low temp.	Race lubricant at low speeds. Needs burnishing before use.	Fair to poor wear life.	Use where req'd. Fair to poor wear life. Good high-load lubricant.
MoS_2 Films Bonded with Organic Binders	Capabilities depend on particular film use at low speed and high to moderate load.	Do not use lubes with hard binders as ball bearing race lubricants.	Best wear life for bonded lubes at moderate to high loads.	Generally good wear life at moderate to high loads.
MoS_2 Films Applied by Gas Blast	Poor wear life.	Use as supplement to sacrificial cage.	Poor wear life.	Poor wear life.
Calcium and Barium Fluorides	Use only at high temperatures to 1700°F.	No information.	No information.	Use at high temperatures 1700°F.

MSFC DOCUMENTATION REPOSITORY - DOCUMENT INPUT RECORD

I. GENERAL INFORMATION

1. APPROVED PROJECT:	2. DOCUMENT/ DRAWING NUMBER:	3. CONTROL NUMBER:	4. RELEASE DATE:	5. SUBMITTAL DATE:
Multi-Program	MSFC-STD-509		10/16/1972	08/15/2003

6. DOCUMENT/DRAWING TITLE:	7. REPORT TYPE:
Standard Lubricant Selection	Standard

8. CONTRACT NUMBER / PERFORMING ACTIVITY:	9. DRD NUMBER:	10. DPD / DRL / IDRD NUMBER:

11. DISPOSITION AUTHORITY (Check One):	12. SUBMITTAL AUTHORITY:	13. RELEASING AUTHORITY:
☒ Official Record - NRRS 8/12/A MA ☒ Reference Copy - NRRS 8/5/A/3 (destroy when no longer needed)	Timothy R. Jett 8-15-03	Gail Gordon 8/18/03

14. SPECIAL INSTRUCTIONS:

15. CONTRACTOR/SUBMITTING ORGANIZATION, ADDRESS AND PHONE NUMBER:	16. ORIGINATING NASA CENTER: MSFC 17. OFFICE OF PRIMARY RESPONSIBILITY: ED32

18. PROGRAMMATIC CODE (5 DIGITS): 62-949-10-E3	19. NUMBER OF PAGES: 13

II. ENGINEERING DRAWINGS

20. REVISION:	21. ENGINEERING ORDER:	22. PARTS LIST:	23. CCBD:

III. REPORTS, SPECIFICATIONS, ETC.

24. REVISION:	25. CHANGE:	26. VOLUME:	27. BOOK:	28. PART:	29. SECTION:

30. ISSUE:	31. ANNEX:	32. SCN:	33. DCN:	34. AMENDMENT:

35. APPENDIX:	36. ADDENDUM:	37. CCBD:	38. CODE ID:	39. IRN:

IV. EXPORT AND DISTRIBUTION RESTRICTIONS

- ☐ Privacy Act (see MWI 1382.1)
- ☐ Proprietary (see MPD 2210.1)
- ☐ Patent (see MPG 2220.1)
- ☐ ITAR (see MPG 2220.1)
- ☐ EAR (see MPG 2220.1)
- ☐ Other ACI (see NPG 1620.1 and MPG 1600.1) _____
- ☒ No statutory or institutional restrictions applicable -- material may be electronically distributed to user in the NASA domain

V. ORIGINATING ORGANIZATION APPROVAL

40. ORG. CODE:	41. PHONE NUMBER:	42. NAME:	43. SIGNATURE/DATE:
ED32	(256) 544-2514	Timothy R. Jett	Timothy R. Jett 8-15-03

VI. TO BE COMPLETED BY MSFC DOCUMENTATION REPOSITORY

44. RECEIVED BY:	45. DATE RECEIVED:	46. WORK ORDER:
Tammy Wise	10-15-03	